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The Antenna Laboratory

Department of Electrical Engineering

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QUARTERLY ENGINEERING REPORT
MICROWAVE TRANSMISSION THROUGH RADOMES

For Period 1 September 1955 to 30 November 1955

Contract AF 33(616)-3212
Task No. 41547

655-1

1 December 1955

The Ohio State University
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Columbus, Ohio

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QUARTERLY ENGINEERING REPORT
655-1

REPORT
by
THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION
COLUMBUS 10, OHIO

Cooperator	Air Research and Development Command Wright Air Development Center Wright-Patterson Air Force Base, Ohio
Investigation of	Microwave Transmission Through Radomes
Contract No.	AF 33(616)-3212
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Submitted by	Antenna Laboratory Department of Electrical Engineering
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ABSTRACT

Efforts to obtain useful numerical results from the rigorous mathematical solution for the field distortion produced by a spherical radome are continuing.

Proposed simple methods of computing the error of a small or highly streamlined radome design are being evaluated by studying a wedge-shaped radome.

QUARTERLY ENGINEERING REPORT

A. SPHERICAL RADOME THEORY

A rigorous solution for the fields of a dipole enclosed in a spherical radome was derived in Report 531-3.[1] Difficulty has been encountered in obtaining useful information from the solution because:

1. the solution is in the form of an infinite series;
2. the series is slowly convergent in many cases of interest; particularly if the dipole is displaced appreciably from the center of the radome;
3. the functions involved in the series solution are incompletely tabulated; and
4. The parameters of the radome occur in the solution in a complicated manner requiring the evaluation of a fourth-order determinant in each term of the series solution.

Various attempts have been made to simplify this solution. A simplified approximate solution valid for large spherical radomes with small dipole displacements was derived in a paper presented at the 1955 Radome Symposium.[2] However, experimental measurements indicate that this approximation is too inaccurate for many radome sizes and dipole displacements of interest.

To extend the present tables of spherical Bessel functions, the Harvard Computation Laboratory was requested to compute these functions for orders up to 100 and arguments up to 100. It is understood that these extended tables will be completed in the near future. The Computation Branch at Wright Air Development Center has been requested to extend the existing tables of associated Legendre functions. In addition, tables of the fourth-order determinants mentioned above have been computed at Ohio State University for a number of spherical radomes. Thus, spherical radome calculations are now feasible for cases in which the solution converges within 30 terms, and may be feasible to 100 terms when the extended tables of functions become available.

It is believed that this problem involves the same phenomena which are so troublesome in small streamlined radomes, particularly if the included wedge angle is small and if its vertex is only a few wavelengths from the antenna. Also the same phenomena should exist for long, highly streamlined radomes having very high incidence angles where the vertex is a considerable distance from the antenna. Yet, the wedge provides a more convenient computational problem than, say, a conical radome, especially if the computations are to be carried out by hand. Any theory and techniques found useful for wedges will most likely be applicable also to actual streamlined radomes. Also, even though these hand computations of the wedge may not yield the precision ultimately required for boresight error calculations, they should serve as a convenient tool for rapidly evaluating a proposed system of computational approximations and procedures; then we would expect that the accuracy of the best wedge-computation procedure could be increased by use of longer, more involved machine computations.

Measurements have been made of the fields along the y-axis of an antenna with and without the radome shown in Fig. 1. Far-field calculations based on measurements taken with the radome present agree closely with measured far-field patterns, as shown in Fig. 2. It was desired, however, to predict the far-field patterns without having to make use of the measured near-fields with radome. As a first attempt at this, it was assumed that the y-axis fields with radome were related to the unperturbed fields by the plane-wave plane-sheet transmission coefficient of the radome walls. In addition, allowance was made for an outward refractive shift in each ray passing through the radome as indicated in Fig. 3. The rays were all assumed to be parallel to the antenna axis as in Fig. 3. The refractive shift predicted a region of zero field intensity near the radome vertex, somewhat resembling the measured fields in that vicinity.

Using the y-axis fields measured in the absence of the radome, the transmission coefficient and the refractive shift were applied, after which an integration was performed to compute the far-field pattern. The results were poor, as shown in Fig. 2. Similar calculations might be expected to be quite accurate when applied to a large, directive antenna having a well-collimated beam even though insufficiently accurate for a small antenna.

The antenna in use had a beam-width of 23° to the half-power points. To test the validity of the parallel-ray picture, an automatic phase plotter was used to obtain equiphase contours near the antenna without radome. A set of curves was then plotted orthogonal to the equiphase contours to show the paths of maximum phase slope. These

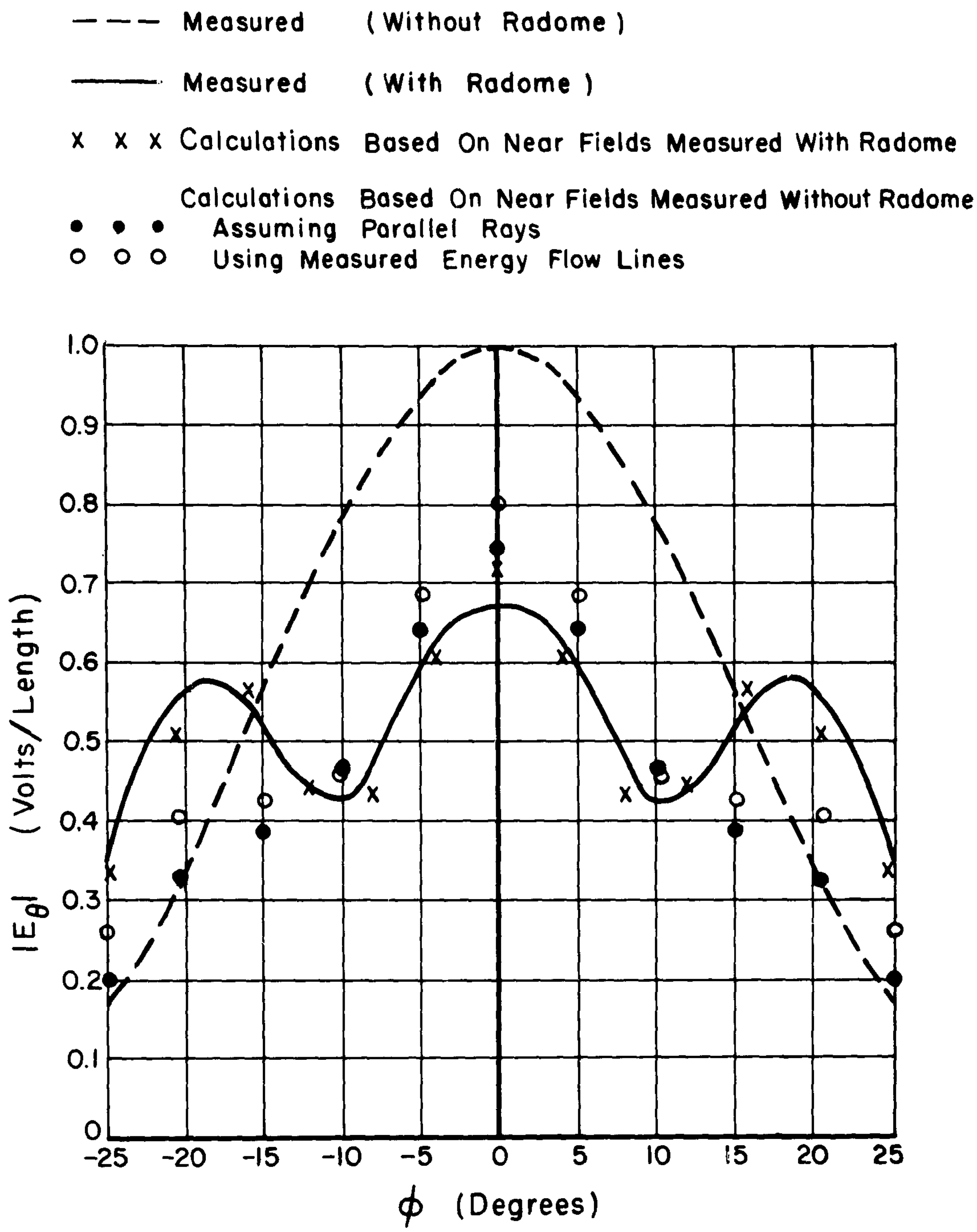

Fig. 2. Measured and Calculated H-Plane Patterns of Antenna With Wedge Radome

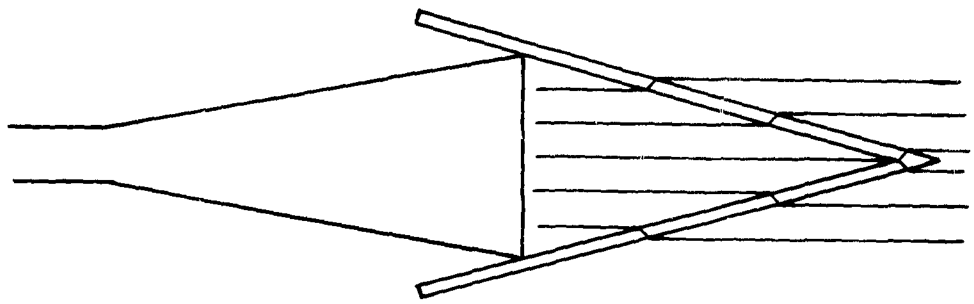

Fig. 3. Parallel-ray transmission through radome.

are (loosely) called energy flow lines and have the appearance shown in Fig. 4. If it is assumed that the energy flow lines are not greatly

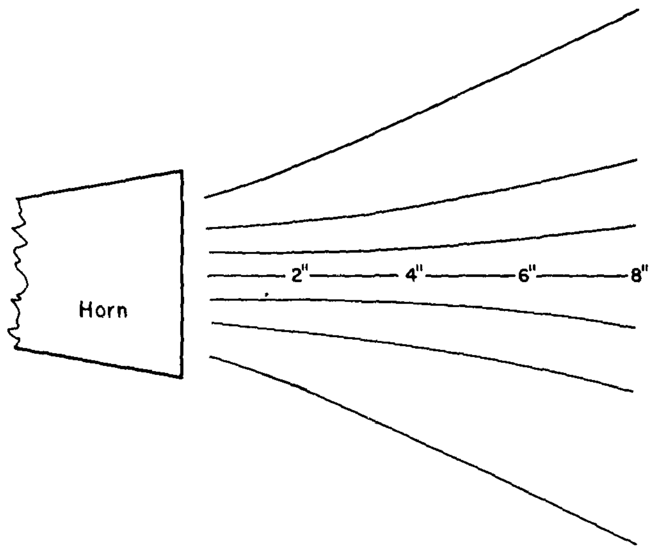

Fig. 4. Measured energy flow map for horn antenna at 9400 mc.

altered by the presence of a radome, a measured energy flow map provides a method of assigning an angle of incidence to each ray as it passes through the radome. This was done in an attempt to obtain more accurate calculations of the antenna pattern with radome. Using the y-axis fields measured in the absence of the radome, the refractive shift and the transmission coefficient appropriate to each ray were applied. The resulting far-field calculations (Fig. 2) show fair agreement with measurements, and are a substantial improvement over the parallel-ray theory.

The fact that these calculations still show some deviation from the measured pattern is quite typical of the present state of the art regarding small, streamlined radomes. Efforts are being made to develop a more accurate mathematical model of the radome, while at the same time keeping the procedure as simple and practical as possible. It is believed that the most serious sources of error are:

1. the use of plane-wave plane-sheet transmission coefficients with a field which is far from being a plane wave and with a dielectric body which is far from being an infinite plane sheet, and
2. the projection of the fields from the radome surface to the y-axis by the use of energy flow lines measured in the absence of the radome.

The situation might be improved by application of the theory derived in Section IV of Report 531-12[5]. A reference plane S would be chosen near the antenna aperture, and a plane wave would be considered incident on the radome from a distant source. It would be necessary to analyze transmission through the radome only for the incident plane wave, rather than for the complicated Fresnel-zone fields of the antenna. A polarization current method[6] for describing the plane-wave transmission through the radome appears to be promising. The effect of the radome would be accounted for in terms of scattering by the polarization currents flowing in the dielectric material.

Our understanding of the problem might be increased by analyzing a less streamlined wedge. If the energy flow lines, the transmission coefficient, and the refractive shift procedure yielded accurate results in this case, it would indicate that the high angles of incidence and the sharp vertex of the streamlined wedge are in some way responsible for the imperfect results achieved thus far.

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